[redacted]

[redacted]

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

June 1942 as
Advance Restricted Report

EFFECT OF AN AROMATIC MIXTURE ADDED TO TWO 100-OCTANE FUELS ON ENGINE TEMPERATURES AND FUEL CONSUMPTION

By Alois Krsek, Jr., and Anthony W. Jones

Aircraft Engine Research Laboratory
Cleveland, Ohio

NACA

WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

EFFECT OF AN AROMATIC MIXTURE ADDED TO TWO 100-OCTANE FUELS ON ENGINE TEMPERATURES AND FUEL CONSUMPTION

By Alois Krsek, Jr., and Anthony W. Jones

SUMMARY

Tests were conducted with an air-cooled cylinder on two fuels rated at approximately 100-octane number by the C.F.R. aviation method with and without a 40-percent addition of an aromatic mixture. The aromatic mixture consisted of 50 percent toluene, 37.5 percent xylene, and 12.5 percent benzene, the percentage being determined on a volume basis.

The data obtained indicate that the aromatic mixture had little or no effect on engine temperatures, indicated mean effective pressure, or indicated specific fuel consumption in the fuel-air ratio range used by present-day aircraft engines. The data also indicate that in the rich region the aromatic fuel in some cases gave a lower specific fuel consumption than did the straight paraffin fuel.

INTRODUCTION

The effect of additions of aromatics on the performance of several 100-octane fuels was reported in reference 1, which was written upon the recommendation of the NACA Subcommittee on Aircraft Fuels and Lubricants. It is shown in reference 1 that certain benefits can be realized from the addition of aromatics. There is some question regarding possible detrimental effects of aromatics and the advisability of using aromatics in aircraft fuels. It has been believed that aromatics cause higher engine temperatures, which would prohibit their use in aircraft fuels. The test work reported in reference 1 was conducted on a liquid-cooled cylinder. Sufficient temperature data were not obtained to make a complete temperature study. For this reason, it was decided to conduct further tests, using an air-cooled cylinder to investigate the effects of an aromatic mixture on engine temperatures. The air-cooled cylinder is better suited for temperature studies than the liquid-cooled cylinder because the higher temperature areas in the air-cooled cylinder respond more to differences in heat input.

FUELS TESTED

NACA fuels 9 and 11, described in reference 1, were used in these tests. Each fuel was used with and without a 40-percent addition of an aromatic mixture. This mixture, which had been used in previous test work on aromatics, consisted of 50 percent toluene, 37.5 percent xylene, and 12.5 percent benzene on a volume basis. For convenience, the aromatic blend consisting of 60 percent fuel 9 and 40 percent mixed aromatics will be designated fuel 9B in this report with the same blend of fuel 11 designated 11B.

The octane number by the C.F.R. aviation method (reference 2) and the tetraethyl lead content were approximately the same for both fuels. Fuel 9, having an octane number of 97.9, contained 2.91 ml tetraethyl lead per gallon and fuel 11, having an octane number equivalent to isooctane plus 0.01, contained 3.00 ml tetraethyl lead.

TEST PROCEDURE

Tests were conducted on a Wright G-200 cylinder mounted on a C.U.E. crankcase. The following conditions were held constant during all the tests:

Engine speed, rpm	2000
Spark advance, deg B.T.C.	20
Compression ratio	7.0
Inlet-air temperature, deg F	250
Inlet-air pressure, in. Hg abs:	
Fuel 9	26
Fuel 11	21
Cooling-air pressure drop, in. water	3

The first tests were made with fuels 9 and 9B, with the inlet-air pressure adjusted so as to remain below the incipient knock level over the entire fuel-air range. After the tests with fuel 9 were completed, the engine was used for a different type of test before the work was continued with fuel 11. When fuel 11 was tested, it was necessary to lower the inlet-air pressure to 21 inches of mercury absolute to avoid knock, although fuel 11 had a slightly higher octane rating than fuel 9. An examination of the cylinder, the piston, and the rings after the tests did not give an explanation for the lower inlet-air pressure required by fuel 11.

TEST RESULTS

Engine Performance

Performance data for fuels 9, 9B, 11, and 11B are shown in figures 1 and 4. Fuel 9 shows a higher indicated mean effective pressure and lower indicated specific fuel consumption than fuel 9B in the lean region below a fuel-air ratio of 0.065 but shows no apparent difference in the rich region. Fuels 11 and 11B show equal performance in the lean region with the fuel blended with aromatics showing an advantage in the rich region. The volumetric efficiencies obtained with the straight fuels were from 0.75 to 1.50 percent higher than those obtained with the blended fuels.

Figures 2 and 5 present the performance data on a lean- and rich-mixture basis, the abscissa scale used being the ratio of the fuel-air ratios obtained to the chemically correct or theoretical fuel-air ratio for perfect combustion. Any vertical displacement of the fuel-consumption curves plotted on a percent-lean or a percent-rich basis is due either to a difference in net or lower heating value or to a difference in thermal efficiency of the fuels in the engine or to both. As the ratio of the net or lower heating values of any two fuels remain constant, their consumption curves would be parallel, provided their thermal efficiencies were identical. The consumption curves for fuels 9 and 9B show a divergence in the lean and in the rich regions, indicating that the blend has a thermal efficiency different from that of the straight fuel. The consumption curves for fuels 11 and 11B are practically identical, indicating that the thermal efficiencies of the fuels are inversely proportional to their lower heats of combustion.

Engine Temperatures

For fuels 9 and 9B at fuel-air ratios greater than 0.07 there was no difference in the engine temperatures as shown in figure 3 - average head; average barrel; rear spark-plug bushing; cylinder barrel, middle, rear; above cylinder flange, rear; center of head between valves; exhaust end zone; and inlet end zone. For fuel-air ratios leaner than 0.07, the temperatures for the straight fuel were about 15° F higher than for the blended fuel. Higher temperatures were also recorded for fuel 11 in the lean region, but in the rich region the temperatures obtained with fuel 11B were, in general, 15° F higher than those obtained with the straight fuel, as shown by figure 6.

The largest difference occurred in the temperature of the exhaust gases from fuels 11 and 11B. In the fuel-air ratio range from 0.070 to 0.105, the exhaust temperatures from fuel 11B were 90° F higher than from fuel 11. The exhaust temperatures from fuel 9B were consistently higher than from fuel 9 over the entire fuel-air range, with a maximum difference of 50° F in the rich region. The temperatures recorded at the exhaust-valve guide were 20° F higher for fuels 9B and 11B than for fuels 9 and 11 within the fuel-air ratio range of 0.068 to 0.110. With mixtures leaner than 0.068, there was no temperature difference between the straight fuels and their aromatic blends. The maximum spark-plug-electrode temperatures for each fuel and its aromatic blend were almost identical. As the mixtures were enriched, the temperatures for the fuels with the aromatic blend decreased less than the temperatures for the straight fuels.

ANALYSIS OF TEST RESULTS

In the general rating and comparing of fuels from consideration of economy, much emphasis is placed on the net or lower heating values of the fuels in question. The usual assumption is made that the fuel with the highest net heating value will perform with the lowest indicated specific consumption. It is known that indicated specific fuel consumption is proportional to the product of several factors, such as cycle efficiency, combustion efficiency, and heat of combustion. These factors are functions of the many variables introduced by the fuel, the engine, and conditions of engine operation. Some of the variables that influence cycle efficiency are speed of combustion, specific heats of the combustion gases, heat of combustion, combustion efficiency, expansion ratio, and heat losses. The variables that influence combustion efficiency include equilibrium constants, temperatures, time, and combustion products. The heat of combustion or the heating value of a fuel is entirely dependent upon the chemical nature of the compound. Since the heat of combustion is determined under conditions very different from actual engine conditions, these variables enter into the engine combustion process as deleterious or compensating agents.

Upon consideration of the data on aromatic fuels given in reference 1 and the data included here, it is evident that some type of compensation was occurring. The higher fuel consumptions expected from the aromatic fuels because of their lower net heating values do not appear in the test data. For this reason, the aromatic fuels should not be penalized because of their lower net heating values.

Higher combustion temperatures were anticipated with the aromatic fuels because of their lower hydrogen-carbon ratios, compared with the straight fuels. A lower hydrogen-carbon ratio would indicate a smaller quantity of water formed and a reduction in heat capacity of the combustion gases. The exhaust-gas temperatures (fig. 6) show this reduction in heat capacity of the combustion gases. It is interesting to note that tho difference in exhaust temperatures did not appear in the head and the cylinder temperatures.

CONCLUSIONS

1. An aromatic mixture up to 40 percent, when added to current paraffinic aviation fuels, results in a small decrease in indicated mean effective pressure in the leaner portion of the fuel-air range of practical interest, 0.065 to 0.100.

2. The aromatic mixture showed no effect on the indicated specific fuel consumption other than a possible decrease in specific fuel consumption in the rich region and a possible increase in consumption in the region of fuel-air ratios leaner than 0.070.

3. Fuels containing up to 40 percent aromatics should have their consumption rates determined by performance in an engine and not estimated by a comparison of heating values.

4. The aromatic mixture caused a decrease in volumetric efficiency of about 1 percent.

5. The temperature differences caused by the aromatic mixture in the engine head and the cylinder were of no practical importance.

6. The maximum spark-plug-electrode temperatures for each fuel tested and its aromatic blend were identical.

7. The aromatic mixture caused a 90° F rise in exhaust gas temperature when used with one of the two fuels tested.

From considerations of engine temperatures, indicated specific fuel consumption, and indicated mean effective pressure, the data presented herein indicate that aromatics up to 40 percent by volume can be added to current aviation fuels with no appreciable deleterious effects.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

REFERENCES

1. Biermann, Arnold E., Corrington, Lester C., and Harries, Myron L.: Effect of Additions of Aromatics on the Knocking Characteristics of Several 100-Octane Fuels at Two Engine Speeds. NACA ARR, May 1942.

2. Anon.: Test Procedures and General Information in Current Use in the Development and Utilization of Aviation, Motor, and Automotive Diesel Fuels. Cooperative Fuel Res. Comm., May 1941.

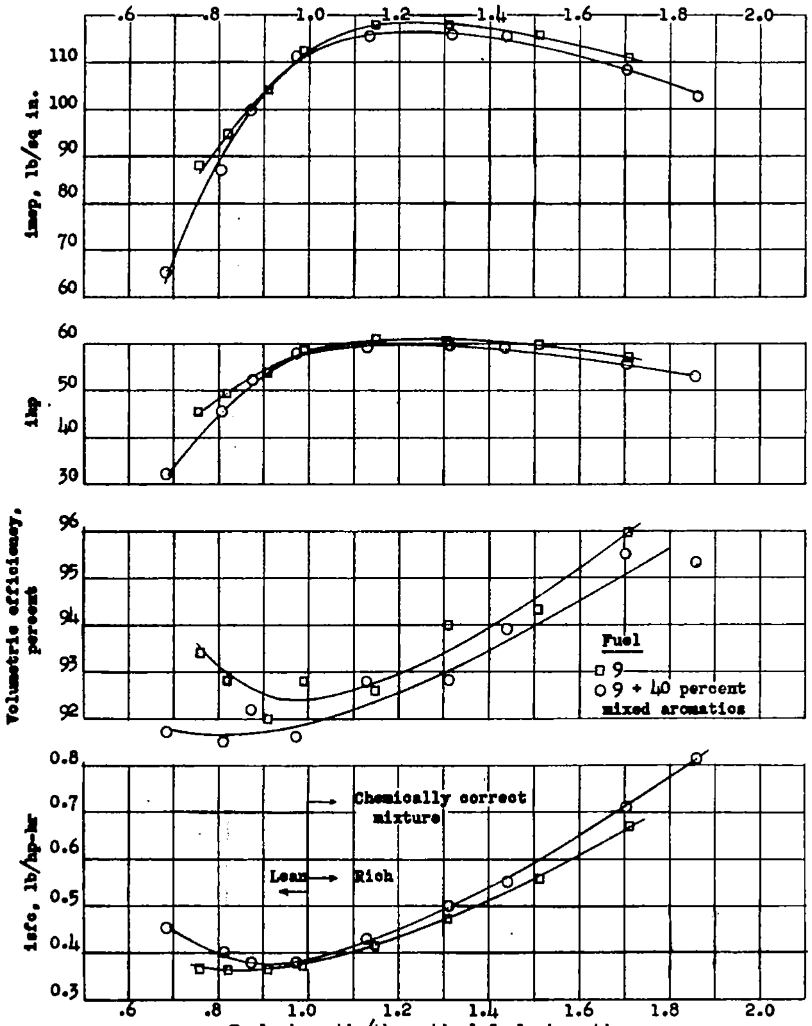

Figure 2. - Relation between fuel-air ratio on a rich and lean basis and engine performance for NACA fuel 9 with and without addition of 40 percent mixed aromatics. Wright G-200 cylinder; engine speed, 2000 rpm; spark advance, 20°; compression ratio, 7.0; inlet-air pressure, 26 inches Hg absolute; inlet-air temperature, 250°F; cooling air pressure drop, 3.0 inches water.

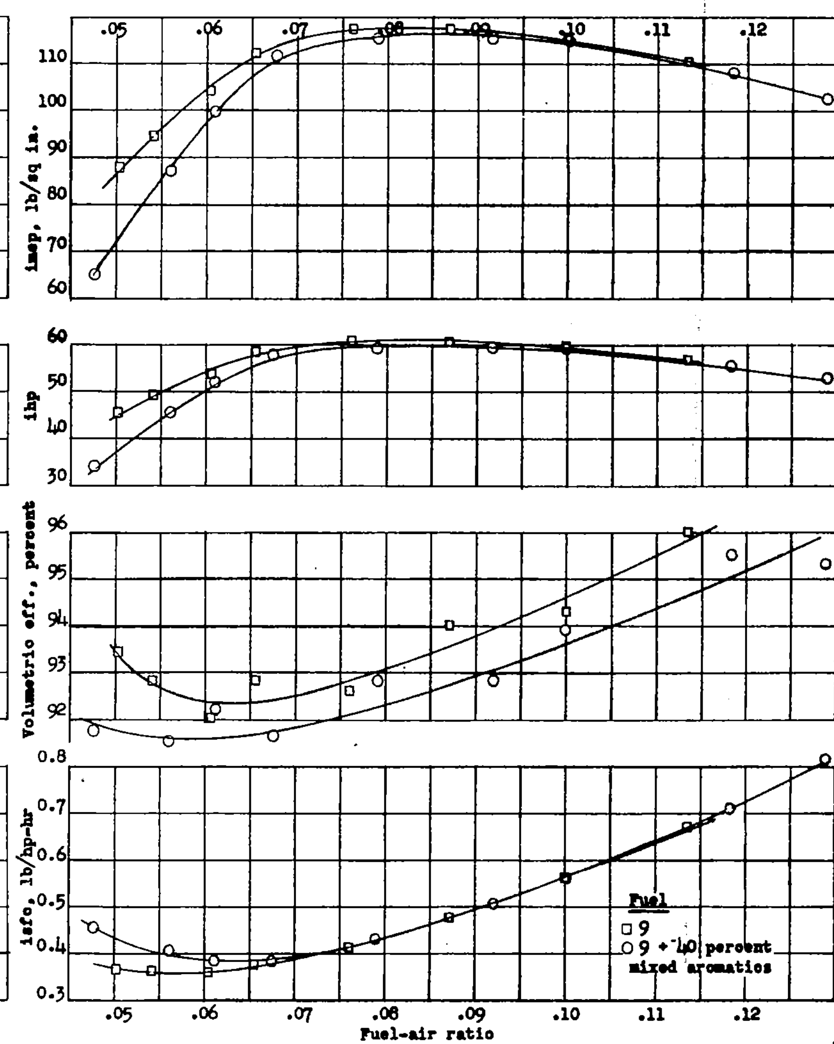

Figure 1. - Relation between fuel-air ratio and engine performance for NACA fuel 9 with and without addition of 40 percent mixed aromatics. Wright G-200 cylinder; engine speed, 2000 rpm; spark advance, 20°; compression ratio, 7.0; inlet-air pressure, 26 inches Hg absolute; inlet-air temperature, 250°F; cooling air pressure drop, 3.0 inches water.

NACA

Figs. 1, 2

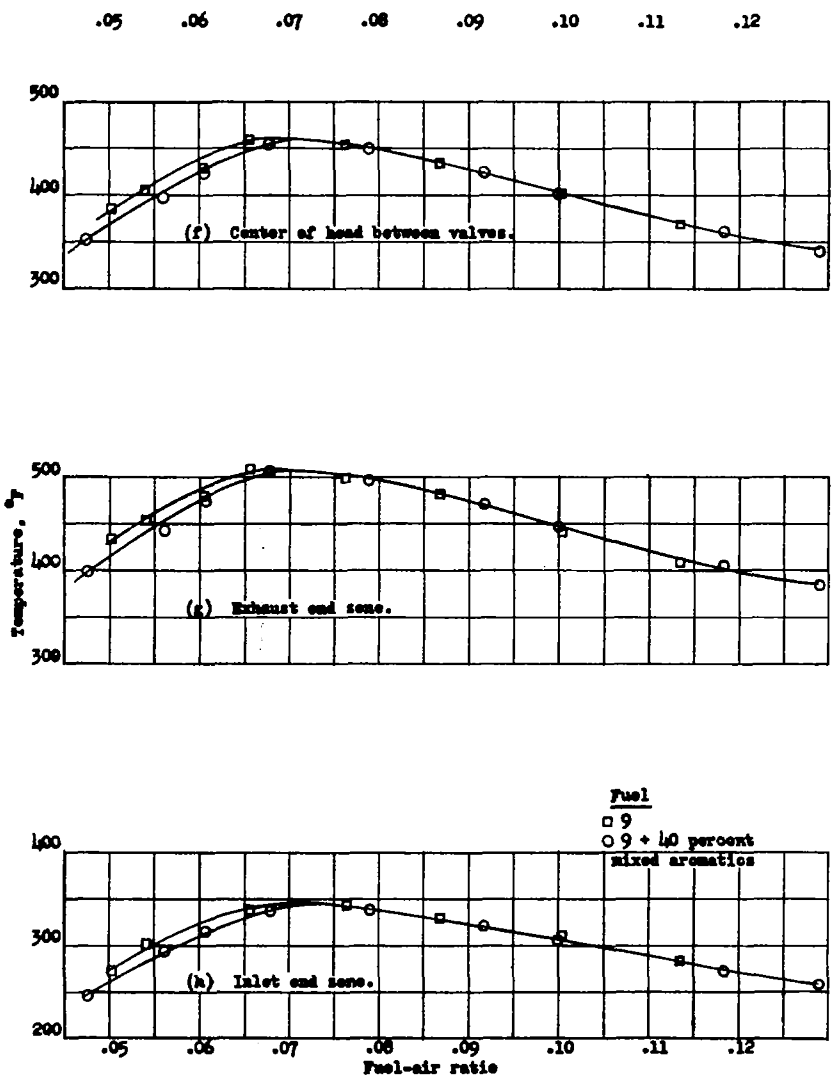

Figure 3. - Continued.

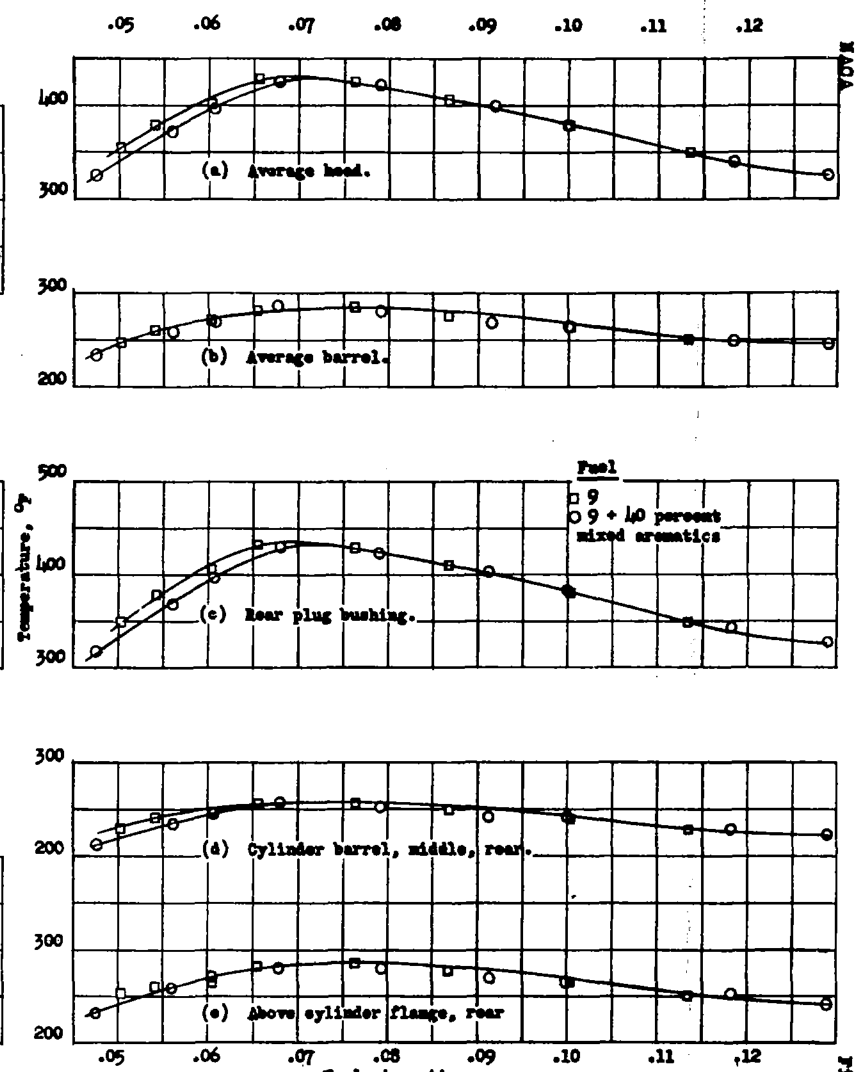

Figure 3. - Relation between fuel-air ratio and engine temperatures for NACA fuel 9 with and without addition of 40 percent mixed aromatics. Wright G-200 cylinder; engine speed, 2000 rpm; spark advance, 20°; compression ratio, 7.0; inlet-air pressure, 26 inches Hg absolute; inlet-air temperature, 250°F; cooling pressure drop, 3.0 inches water.

Fig. 3a-h

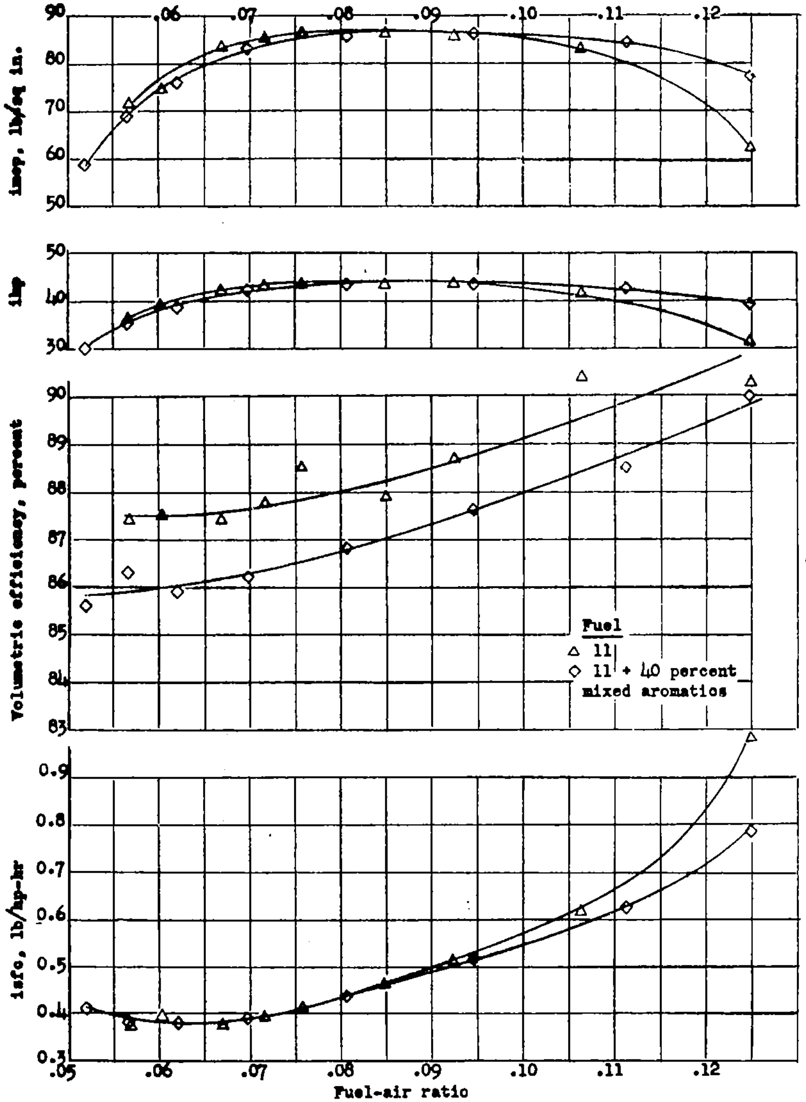

Figure 4. - Relation between fuel-air ratio and engine performance for NACA fuel 11 with and without addition of 40 percent mixed aromatics. Wright G-200 cylinder; engine speed, 2000 rpm; spark advance, 20°; compression ratio, 7.0; inlet-air pressure, 21 inches Hg absolute; inlet-air temperature, 250°F; cooling-air pressure drop, 3.0 inches water.

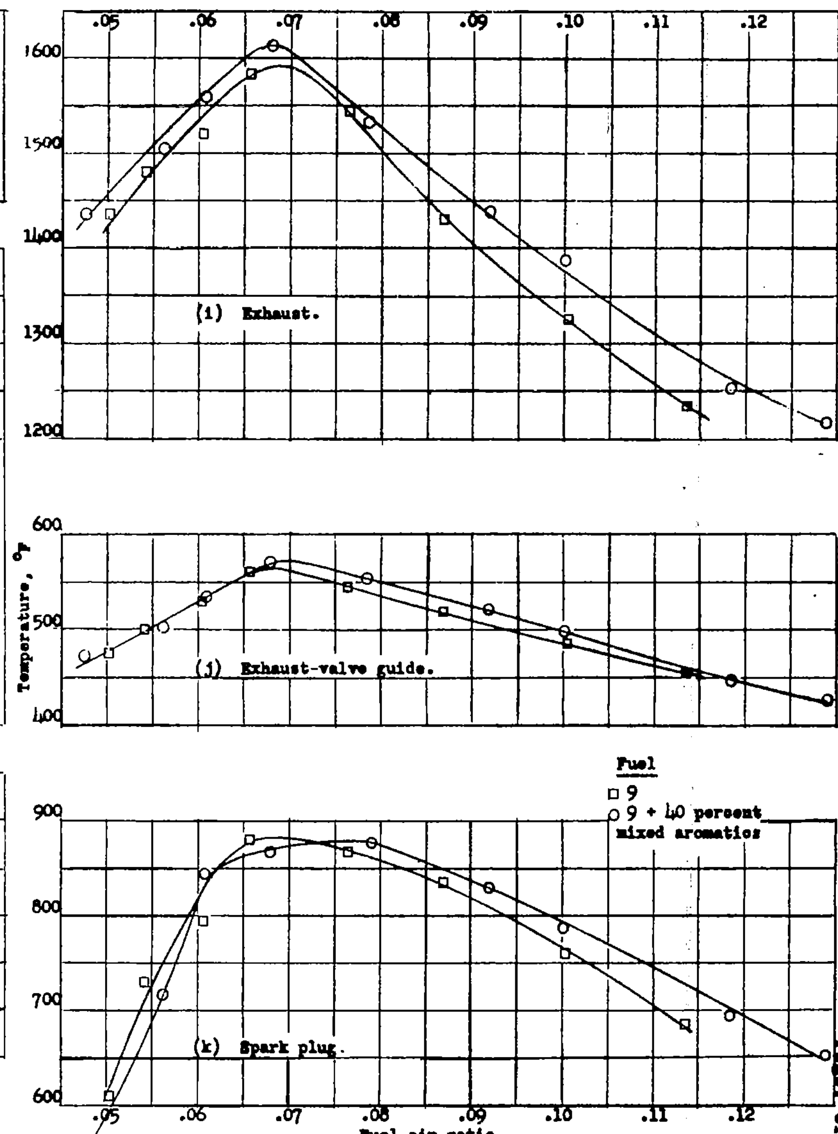

Figure 3. - Concluded.

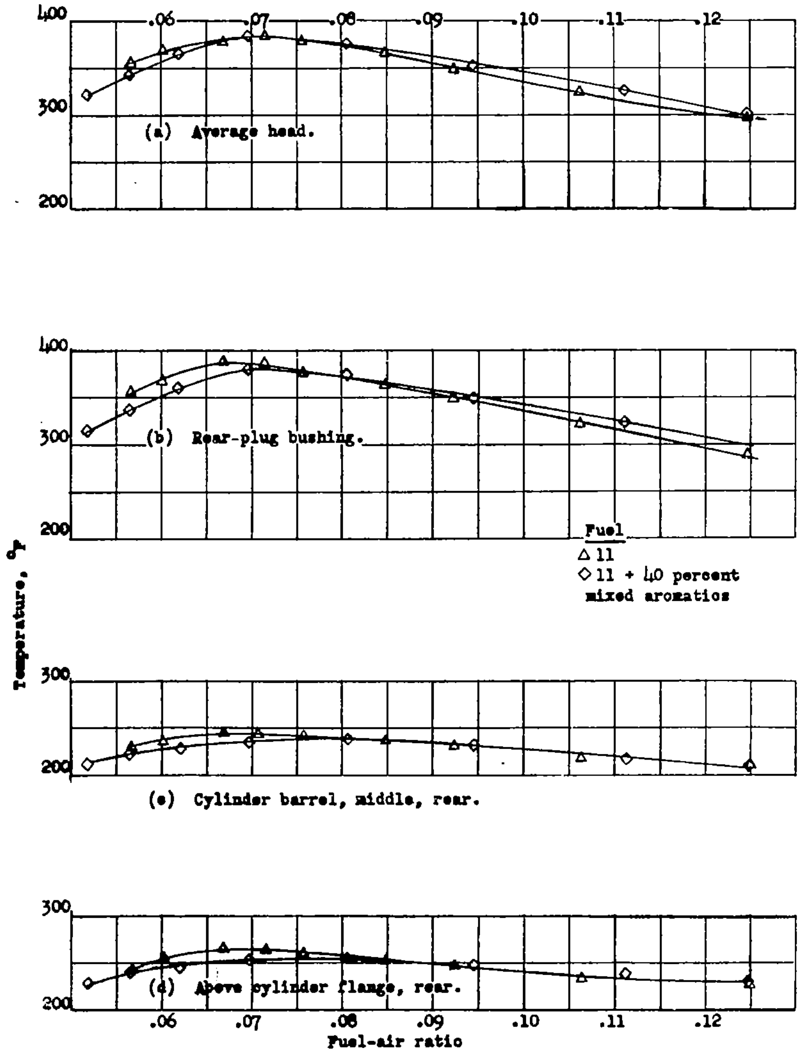

Figure 6. - Relation between fuel-air ratio and engine temperatures for NACA fuel 11 with and without addition of 40 percent mixed aromatics. Wright G-200 cylinder; engine speed, 2000 rpm; spark advance, 20°; compression ratio, 7.0; inlet-air pressure, 21 inches Hg absolute; inlet-air temperature, 250°F; cooling-air pressure drop, 3.0 inches water.

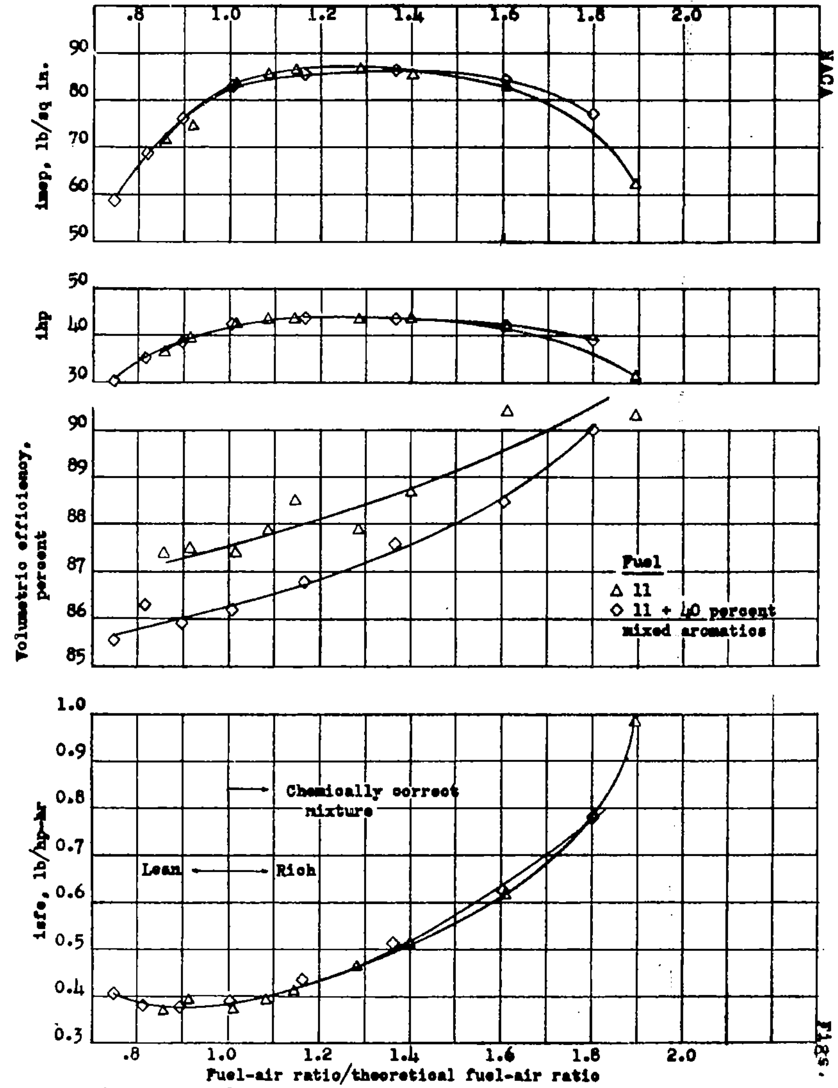

Figure 5. - Relation between fuel-air ratio on a rich and lean basis and engine performance for NACA fuel 11 with and without addition of 40 percent mixed aromatics. Wright G-200 cylinder; engine speed, 2000 rpm; spark advance, 20°; compression ratio, 7.0; inlet-air pressure, 21 inches Hg absolute; inlet-air temperature, 250°F; cooling-air pressure drop, 3.0 inches water.

NACA

Figs. 5,6

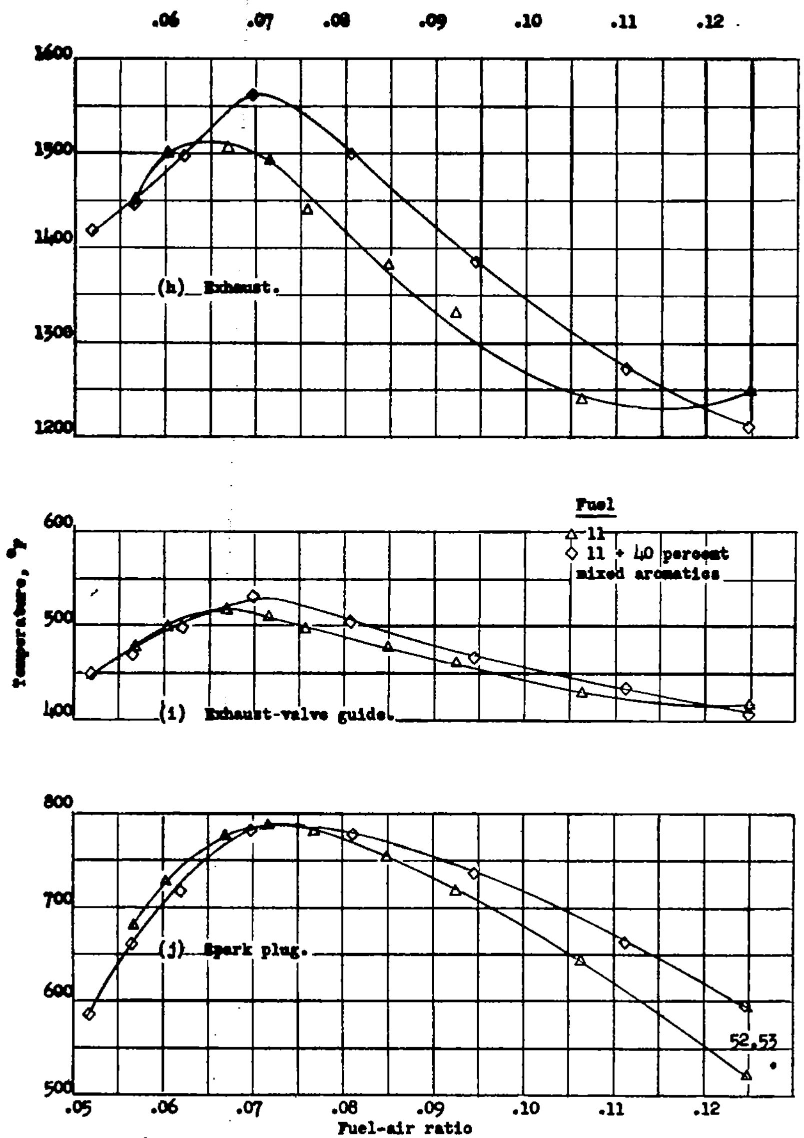

Figure 6. - Concluded.

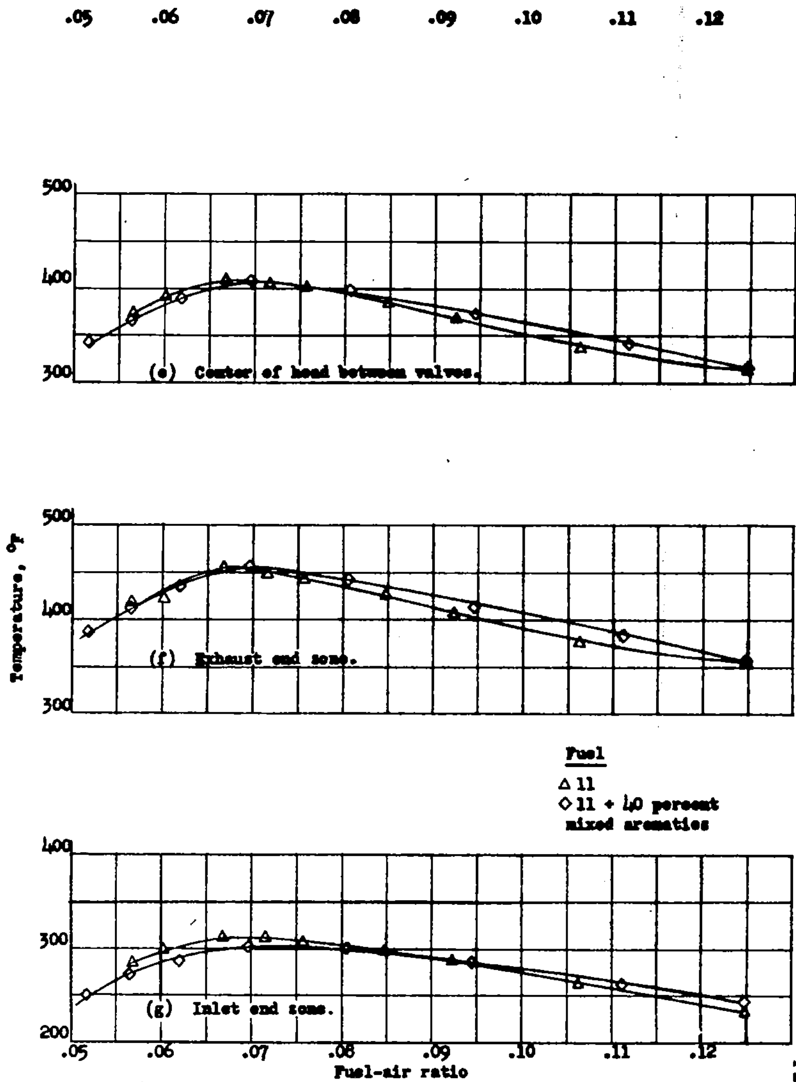

Figure 6. - Continued.

NACA

Fig. 6e